2002 NEC & Beyond

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Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

The 2002 *National Electrical Code (NEC)* has been published by the National Fire Protection Association (NFPA), and will be enacted into law by many states and local jurisdictions after January 1, 2002. My column in *HP86* covered changes to the *NEC,* sections 690.2 through 690.14. This column will cover changes in the remainder of Article 690, and discuss the start of the 2005 *NEC* activities.

About 40 people in the PV industry worked on a set of 32 proposed changes to the 2002 *NEC.* Others inside and outside the industry had input, as can anyone who will take the time to properly fill out the required form.

Many of these proposals were not well substantiated, and were rejected on the first cycle of the three-year process. Several changes were made during the public comment phase. The Code Making Panel (CMP-3) had their say, and then the NFPA correlating committee made the final revisions and edits.

The exact contents of Article 690 for the 2002 *NEC* will not be repeated here due to space restrictions. Everyone designing and installing PV systems is encouraged to get a copy of the compete 2002 *NEC,* and better yet, the 2002 *NEC Handbook.*

690.45 Size of the Equipment Grounding Conductor
This section was added to reflect recent research that shows that the equipment-grounding conductors for module source and output circuits must essentially be as large as the circuit conductors (at least they must have an ampacity of 1.25 times the short-circuit current). Oversizing the equipment-grounding conductors when the circuit conductors are oversized for voltage drop is still required, but they don't have to be any larger than the circuit conductors.

If the system is protected by a Section 690.5 ground-fault detection device, the equipment-grounding conductors are to be sized according to Section 250.122. This sizes the equipment-grounding conductors based on the overcurrent device protecting that circuit.

690.47 Grounding Electrode System
CMP-3 revised this section into two parts. Section A addresses alternating current grounding and Section B addresses DC grounding. All the section really does is refer back to the appropriate AC or DC grounding sections in Article 250.

690.55 Photovoltaic Power Systems Employing Energy Storage
This new section requires a label that will show the maximum operating voltage (including any equalizing voltage) of the system, and the polarity of the grounded conductor. Although most PV systems use a negative ground, some telecommunications systems use positive grounds. The label should be placed near the main system disconnects.

690.56 Identification of Power Sources
Part A deals with the marking required on the outside of buildings with stand-alone PV systems. Part B covers the exterior markings on buildings that have utility service and PV systems. In both cases, the requirement is to indicate the locations of the main disconnects for all sources of electrical energy to a building—including renewable, utility, or backup generator sources.

690.71 (D) Battery Nonconductive Cases and Racks
This section requires that flooded, lead-acid battery systems operating at over 48 volts nominal (twenty-four, 2 volt cells) have nonconductive racks and cases to minimize the potential for leakage currents, carbon tracks, shocks, and explosions. These problems have been seen on batteries in high-voltage battery banks (100–500 volts). This requirement does not apply to valve-regulated, lead-acid batteries (VRLA) that are sealed, because they normally don't pose similar hazards.

690.71 (E) Disconnection of Series Battery Circuits
This section requires that battery banks operating at more than 48 volts nominal have provisions to disconnect the series-connected cells into sets of 24 cells or fewer for servicing. Bolted or plug-in disconnects are allowed, and the plug-in disconnects do not have to be load-break rated. (A switch that can carry the circuit current, but that is not rated to open the circuit while carrying current is known as a non-load-break rated switch.)

690.71 (F) Battery Maintenance Disconnecting Means
A disconnect (for use by qualified people only) is now required to open the grounded conductor of battery banks operating above 48 volts nominal. This

disconnect may be a non-load-break switch, and it may not unground the rest of the PV system.

690.71 (G) Battery Systems of More Than 48 Volts
Battery systems of more than 48 volts nominal may be (permissive language, not required) operated with ungrounded conductors if several conditions are met. The PV array must be grounded. Any AC and DC load circuits must be grounded. The first two conditions are probably going to be met by certain types of inverters that provide internal ground-circuit isolation between the PV array, the load circuits, and the battery system.

All ungrounded input/output battery circuit conductors will be required to have switched disconnects and overcurrent protection. A ground-fault detector will be required to monitor the battery bank for ground faults.

690.72 (B) Diversion Charge Control
Subparagraph (1) requires that any system using a diversion charge controller have a second independent method of charge control. With diversion controllers, if the diversion circuit fails, the batteries may be overcharged, and can pose hazards (explosions, smoke, and fire). This requirement would apply to both AC and DC diversion controllers.

The code is not specific in the type of independent charge control required. It might be a second diversion controller or a series-type controller set at a slightly higher voltage. One way, when using an inverter with an extra adjustable relay measuring battery voltage, is to have the inverter drive an external relay to open the PV circuit if the diversion controller fails. Xantrex Technologies recommends this method when selling excess energy from the PV array back to the grid as a means of protecting the batteries from overcharge if the grid should fail.

Subparagraph (2) says that the current rating of the DC diversion load, the ampacity of the diversion load circuits, and the rating of the overcurrent device protecting those circuits must be at least 150 percent of the current rating of the charge controller. Of course, the diversion charge controller should be sized to handle the total output of the renewable source.

Clearer Code?
Most of the changes in Article 690 of the 2002 *NEC* make it somewhat clearer. The revisions to the comments in the 2002 *NEC Handbook* should also make it easier to understand the rationale behind the code requirements. Now is the time to start deliberations on the 2005 *NEC,* to improve it as well.

The 2005 *National Electrical Code*
Now that the 2002 *NEC* has been published, work is starting on the 2005 *NEC.* Remember that anyone can submit well-substantiated proposals to the National Fire Protection Association for consideration by the code-making panels.

Since NFPA, Underwriters Laboratories (UL), the Institute of Electrical and Electronic Engineers (IEEE), the International Association of Electrical Inspectors (IAEI), and other organizations have members on the code-making panels, the substantiation for proposals should address any requirements and concerns that those organizations might have, such as compliance with other electrical industry requirements. For example, a proposal suggesting that cables not listed by a recognized testing lab be used in PV systems would not receive much support by the panel members unless it had very good substantiation.

If you are interested in participating in the e-mail discussions of the 2005 code, or attending the meetings, just e-mail me and I will put you on our list for future information. The proposals that we at the Sandia National Laboratories make are well substantiated, and are coordinated with UL and IEEE members before submission.

2005 *NEC* Proposals
Here are a few items that are being discussed and may be proposed for inclusion in the *NEC* or in the appropriate UL standard.

- Some stand-alone inverters may have DC input currents that have RMS (root mean square) AC ripple currents that exceed the average DC currents. Should this RMS value be marked on the inverter, and then used for cable ampacity and overcurrent device ratings?
- Should the grounding point for framed PV modules be placed inside the module junction box to facilitate the equipment-grounding conductor connection? This would minimize the copper-to-aluminum compatibility problem, and keep all the conductors together to minimize the circuit time constant by reducing the circuit inductance.
- Should all PV modules be marked for use with 90°C (194°F) conductors, since very few locations would allow the use of 75°C (167°F) conductors because junction box temperatures usually exceed 70°C (158°F)?
- Should the warning required by *NEC* Section 690.5 (C) be made part of the UL-required marking on the inverter? The warning states that a ground-fault indication may mean that the normally grounded circuit conductors are no longer grounded and may be energized.

- Should inverters that ground the PV array inside the inverter be required to have an external warning stating the grounding method? Should they be required to have terminals large enough to meet code-required, grounding-electrode conductors?
- Should the *NEC* adopt language similar to the European and Japanese standards for ungrounded PV systems up to 120 volts?
- What will the most advanced plug-n-play PV system look like, and what are the safety issues that need to be addressed in the *NEC*?

Questions or comments? If you have questions about the *NEC*, or the implementation of PV systems that follow the requirements of the *NEC*, feel free to call, fax, e-mail, or write me. Sandia National Laboratories sponsors my activities in this area as a support function to the PV industry. This work was supported by the United States Department of Energy under Contract DE-FC04-00AL66794. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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The 2002 *NEC* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA), 11 Tracy Drive, Avon, MA 02322 • 800 344-3555 or 508-895-8300 • Fax: 800-593-6372 or 508-895-8301
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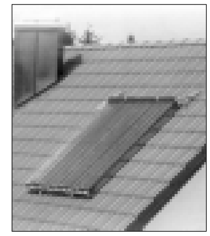

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